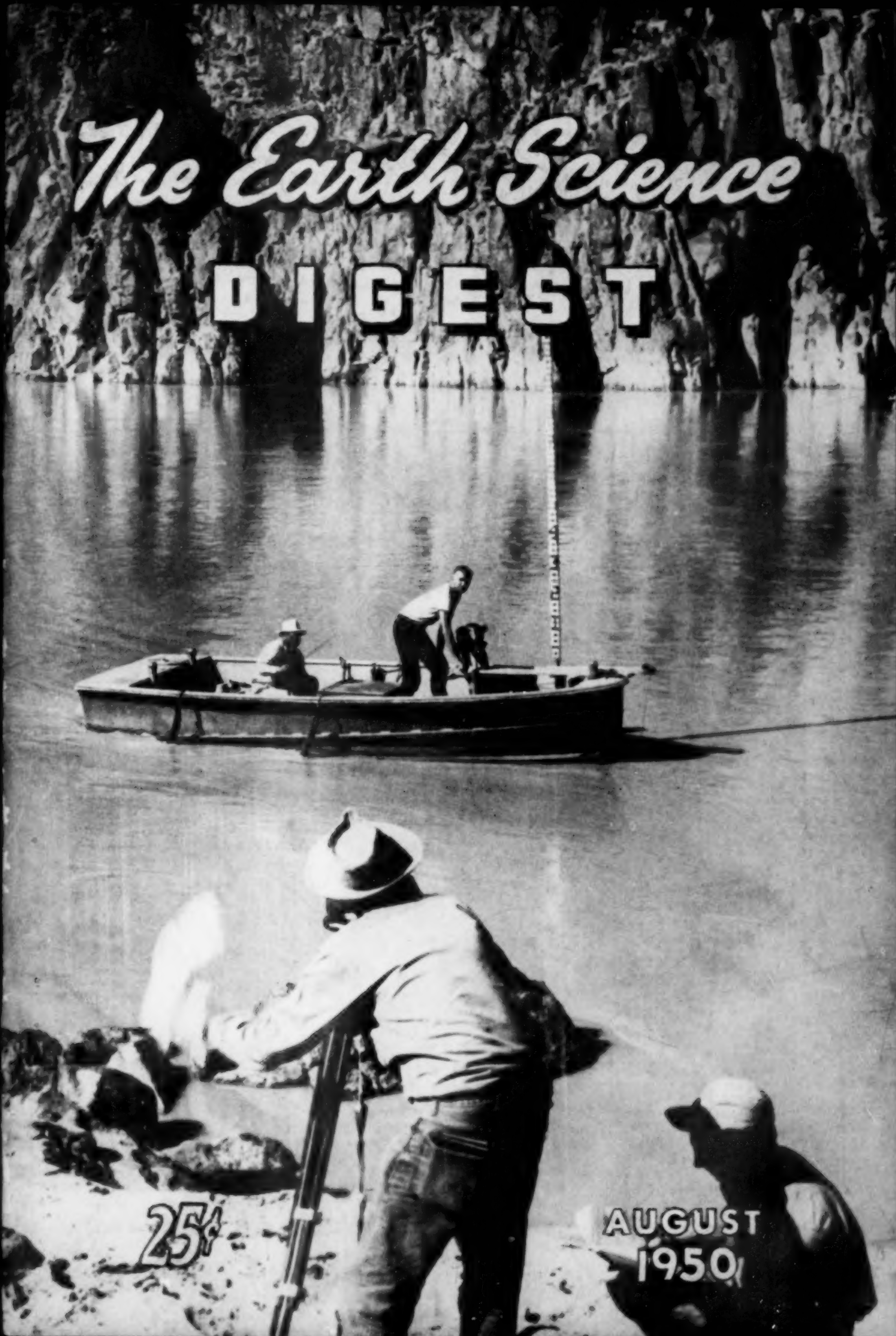
The Earth Science DIGEST



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The Earth Science Digest

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A magazine devoted to the geological sciences.

Jerome M. Eisenberg, Editor

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CONTENTS

Radioactive Areas Located in Upper Michigan by Plane Survey 2

CURRENT STATUS OF ATOMIC RAW MATERIALS — Part II — Robert J. Wright 3

COLUMBIA MINERAL RESOURCES APPRAISED 10

Earth Science Abstracts 12

Water Resources — June 1950 12

SEDIMENTATION STUDIES AT LAKE MEAD — Herbert B. Nichols 13

OPPORTUNITIES FOR LECTURING AND RESEARCH ABROAD UNDER THE FULBRIGHT PROGRAM 22

NEW BOOKS 24

Meetings and Conventions

- Northwest Federation of Mineralogical Societies, Annual Convention. September 2-3, 1950. State Armory, Spokane, Wash.
- Meteoritical Society, Annual Meeting. Sept. 5-7. Museum of Northern Arizona, and Meteor Crater, Flagstaff, Arizona.
- Geological Association of Canada, Annual Meeting. Sept. 11, 1950. Banff, Alberta.
- National Petroleum Association, Annual Meeting, Sept. 13-15. Hotel Traymore, Atlantic City, N. J.
- Mississippi Geological Society, 8th Field Trip, October 13-15. Registration. Lamar Hotel, Meridian, Miss. Oct. 12.
- American Association of Petroleum Geologists; Society of Economic Paleontologists and Mineralogists; Society of Exploration Geophysicists. Pacific Section Annual Meetings. Oct. 19-20. Ambassador Hotel, Los Angeles, Calif.
- Permian Basin Oil Show. Oct. 19-22. Odessa, Texas.

Radioactive Areas Located In Upper Michigan By Plane Survey

WASHINGTON, July 26 — A U. S. Geological Survey investigation hints that the Northern Peninsula of Michigan may contain deposits of radioactive materials. Airborne Geiger counters have located radioactive anomalies in the area. Such radioactivity, however, may be caused by materials such as thorium which are of little interest in the present atomic energy program, and do not necessarily indicate the presence of uranium in quantity worth mining.

The details of the series of flights made over northern Michigan by the Geological Survey's specially equipped plane are contained in a joint report by F. W. Stead, F. J. Davis, R. A. Nelson, and P. W. Reinhardt. Stead and Nelson are members of the Survey. Davis and Reinhardt are from the Oak Ridge National Laboratory. Accompanying the report is a detailed map showing the approximate location of the anomalies in an area of about 1,600 square miles. The work was accomplished during May and June as part of a cooperative program with the U. S. Atomic Energy Commission.

The plane used was a Douglas DC-3A. A total of 60 hours flying time was required to make the Michigan studies, of which 46 hours were spent in actual surveying. All traverses were flown north and south at approximately 500 feet above the ground at quarter-mile intervals. Aerial photographs were used for pilot guidance and the flight path of the aircraft was recorded by a gyro-stabilized, continuous-strip-film camera.

The technique of airborne prospecting for uranium, still in the experimental stage, has in large part incorporated the pioneering development by the Geological Survey and Naval Ordnance Laboratory of aeromagnetic surveying. In this prior work, establishing the true position of the plane in relation to ground points was an important contribution to airborne radioactivity surveying.

The search for radioactive anomalies employs 19 Geiger counters in parallel arrangement. The hard component of cosmic radiation is reduced by a special circuit and by arranging the counter tubes in hexagonal bundles. In this way the back-ground noise due to cosmic radiation is much diminished, and gamma radiation from ground sources can be measured more accurately.

Flying at 500 feet above the ground, the width of the zone from which the radioactivity is measured is at least 1,400 feet, the authors point out. Thus, if the flight paths of the plane are spaced at quarter-mile or 1,320-foot intervals, the entire area should be covered adequately by the airborne radioactivity survey. They explain, however, that small areas of considerable radioactivity might lie unnoticed midway between two flight paths.

The approximate location of each radioactivity anomaly is shown on the accompanying map as a colored dot, but the true position may be in error by as much as a quarter of a mile. This is caused for the most part by local errors of that size in the available base maps, and by blank areas up to 25 square miles in which it was impossible to find and plot recognizable positions. This section of Michigan is extremely rugged and wild.

Copies of the map with explanatory text are available without cost by addressing a request to the Director, U. S. Geological Survey, Washington 25, D. C.

COVER PHOTO

Small boat measurement of the sediment bed depth in the upper end of Lake Mead is the subject of this month's cover photo. See **Sedimentation Studies at Lake Mead,** by Herbert B. Nichols, pp. 13-22. Department of the Interior photo.

CURRENT STATUS OF ATOMIC RAW MATERIALS

ROBERT J. WRIGHT
U. S. ATOMIC ENERGY COMMISSION

PART II OF A TWO-PART ARTICLE

New Pitchblende Discoveries

When prospecting for uranium became active in this country, it was natural that a promising line of attack was to look for geologic associations that would most nearly resemble those of the great uranium deposits abroad. Unfortunately, there has not accumulated the body of geologic knowledge about pitchblende deposits that has grown, over years of experience, for other metals. The pitchblende producing areas of the world are few and widely scattered over the globe. Much of the mining was done behind the cloak of commercial or governmental secrecy. However, the present attention given to atomic raw materials has stimulated research and thought about the problems of uranium geology and, as a result, scientific intelligence about these deposits is slowly growing.

From our present knowledge about pitchblende veins, it is possible to make certain generalizations about the geologic environment which holds true for most of the world's leading uranium producers. At the moment these relationships are little more than rough rules-of-thumb which, no doubt, will require revision in the light of later knowledge, and in most cases the underlying geologic and geochemical explanations are obscure.

First, a large proportion of the deposits are in pre-Cambrian sedimentary rocks or their metamorphic equivalents.

Second, the ores are usually complex mineralogically and cobalt, nickel, and silver minerals are commonly associated with the pitchblende. As we have noted earlier, however, some of the ore in the Lake Athabaska area is an exception to this rule.

Third, the gangue minerals of the veins are primarily carbonates, together with quartz.

Fourth, on the basis of paragenesis the mineralization appears to have occurred in the medium to high temperature range.

Fifth, the veins commonly form in tension fractures.

Sixth, associated igneous rocks are primarily granitic.

Seventh, hematitic alteration of the wall rock and/or the gangue minerals is common.

These, then, are some of the geologic guides which have proved of value in scientific prospecting for uranium veins. The use of these guides has resulted in the discovery of pitchblende at several mines in our western states. These

CHARACTERISTICS OF PITCHBLENDE DEPOSITS

	Erzgebirge district, Czechoslovakia	Shinkolobwe, Belgian Congo	Great Bear Lake, Canada	Lake Athabaska, Canada
1. In pre-Cambrian sedimentary or metamorphic rocks	X	X	X	X
2. Associated Co, Ni, Ag minerals	X	X	X	X
3. Carbonate gangue minerals	X	X	X	X
4. Temperature range	med.	high	high	
5. Fissure filling	X	X	X	X
6. Associated with granites	X	?	X	X
7. Hematitic wall rock alteration	X		X	X

discoveries have been made by examination, with Geiger counter, of ore deposits which appeared favorable on the basis of geology.

One discovery, which at the time received considerable publicity, was made in 1945 at the abandoned Caribou mine. The Caribou mine is in the Colorado Front Range and it had been one of the oldest and richest silver producers in the state. The mine is located a few miles west of Nederland in Boulder County. Small amounts of pitchblende had been produced at several mines in the Central City district to the southeast during operations half a century ago. The fact that high grade silver veins occur not far from a district where pitchblende mineralization was known suggested an area of promise. G. C. Ridland, who had been systematically checking old mine dumps with a Geiger counter, first discovered pitchblende during an examination of the Caribou dumps. A portion of the dump proved radioactive, and it developed that this material had been brought to the surface during the last years of mine operation. This work had taken place in the deepest portion of the mine, the 1040-foot level.

To determine the uranium potentialities of the mine the workings were rehabilitated in 1948. A radiometric reconnaissance of the 1040 level indicated abnormally high radioactivity and pitchblende was found in a silver-lead-zinc vein. Underground exploration is now in progress and only time will indicate the significance of the discovery.

Another similar discovery of pitchblende was made last summer during a reconnaissance of the Coeur d'Alene district, Idaho, by E. E. Thurlow of the Atomic Energy Commission. The Coeur d'Alene district was selected for examination because of several favorable geologic features: cobalt occurs in trace amounts within the ore; silver is an important product; the ore bodies form largely within the sedimentary rocks of the pre-Cambrian Belt series; and the nearby igneous rocks are granites of the Idaho batholith. A Geiger counter reconnaissance of mill products, mine dumps, and underground workings was undertaken. It was found that portions of the lower workings of the Sunshine mine were radioactive and pitchblende bearing veinlets were located. Shortly thereafter pitchblende was also found in the Coeur d'Alene mine.

Like the Caribou deposit, the known radioactive portions of the Sunshine deposit are exposed in the lower mine workings. The pitchblende occurs not within the main Sunshine vein but instead in closely related veinlets in the wall rock. There seems to be particular preference for the north, or footwall, side of the vein. The paragenesis of the Sunshine ore indicates that the pitchblende is among the latest and lowest temperature vein minerals. This contrasts with the ores of Great Bear Lake and other deposits where pitchblende is one of the earliest, high temperature minerals.

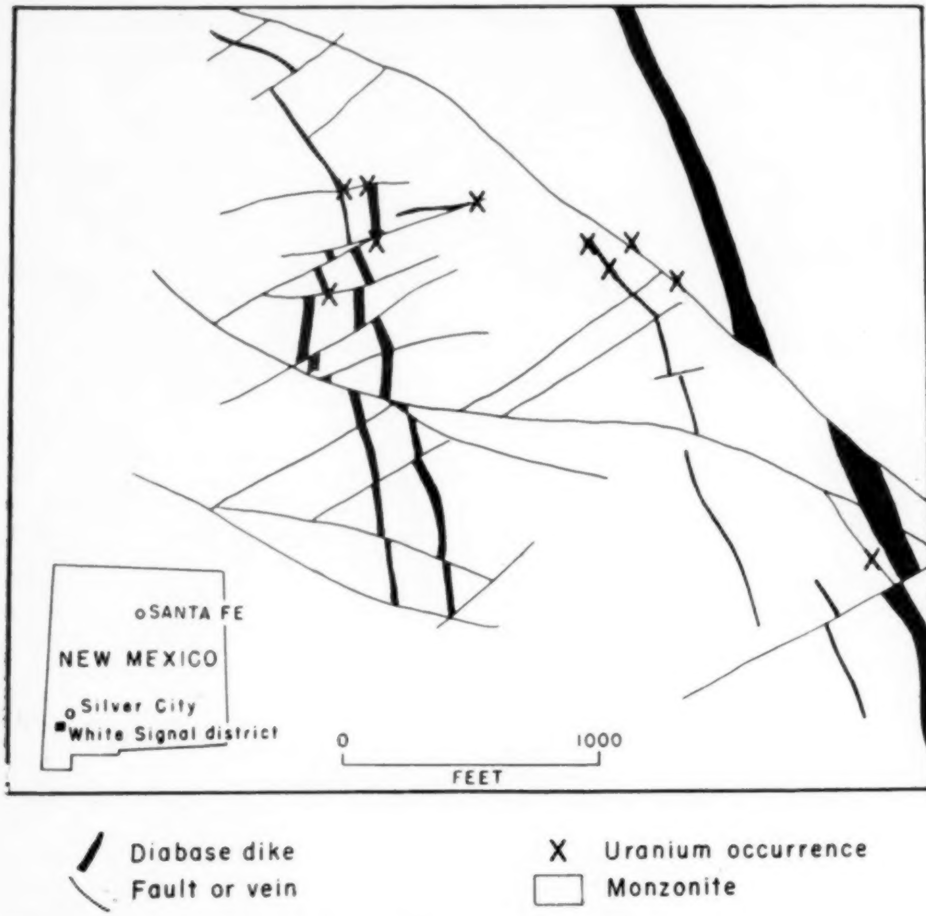
The disc series of uranium in these two mines indicate that pitchblende may be present in ore deposits which have not previously been known to carry radioactive minerals. We expect that further finds of this type will be made. It is not particularly surprising that uranium minerals may remain unrecognized during years of mining operation, because in most cases the pitchblende forms only a small portion of the ore and is not usually distinctive in hand specimens. As a rule, radioactive material can be detected only through use of portable Geiger counters. Any vein deposit having some of the geologic characteristics mentioned before should therefore be checked with a counter.

Deposits of Secondary Uranium Minerals

A second significant trend in our exploration for new uranium deposits is the increasing attention being given to surface outcrops of secondary uranium minerals.

Deposits of this kind are found at various places in this country and abroad. The uranium minerals involved are varied, but the most common representatives are the hydrous uranium phosphates, autinite and torbernite, the hydrous uranium oxide, uranophane, and the hydrous uranium carbonate, schroekingerite. Many of these minerals are bright yellow, orange, and green and are earthy or flaky in appearance. In most places, they are concentrated along structures such as fissures, veins, and dikes, but elsewhere they may have widespread distribution with little structural control. Here is involved a neat point of geologic interpretation. These are the twin horns of this dilemma: do the secondary minerals represent the surface weathering of a vein containing primary pitchblende or, on the other hand, do the secondary minerals represent a concentration of the uranium normally contained, in very small amounts, in all rocks.

If pitchblende is present in a vein, we would normally expect to find hydrous secondary uranium minerals at the weathered outcrop. In this case the surface minerals — the uranium "gossan," we might say — would indicate a primary vein deposit at depth. On the other hand, all rocks contain trace amounts of uranium. It is known that the uranyl ion is quite soluble, particularly in slightly acid waters, so that the uranium in rocks is subject to solution and redistributed by ground water. In this way secondary uranium minerals may be deposited along fissures, shear zones, dikes, or other structures which influence the flow of ground water. Such secondary deposition should be



Cross-section of the White Signal district, N. M., showing the pre-Cambrian granite cut by a complex series of monzonite, diabase and felsite dikes, as well as steeply dipping faults. Nearly all the concentrations of uranium minerals are distributed along the margins of the diabase dikes and the faults. Courtesy of U. S. Atomic Energy Commission.

particularly common in rocks with higher than normal radioactivity — granites, for example. Most granites have been reported to contain ten or more times the average amount of uranium found in the earth's crust. Furthermore, it has been shown by P. M. Hurley, Massachusetts Institute of Technology, that much of the uranium in granite is contained in a form that is readily available to ground water. Instead of being limited to radioactive accessory minerals much of the radioactivity stems from thin coatings of radioactive salts on the surface of mineral grains. Experiments have shown that in less than 24 hours dilute hydrochloric acid removes up to 90% of the radioactivity associated with some granites. On two counts, then, granites are especially favorable rocks for the development of secondary uranium minerals, and, as we have seen earlier, granites are also favorable for the development of primary uranium veins. So the problems of geologic interpretation may be especially acute in granitic terrain.

Marysvale is a small town in the southern part of Utah which is currently undergoing a uranium boom. The excitement here is due to the fact that recently discovered secondary uranium ores are being mined and sold. The main uranium mineral is autunite with smaller amounts of schroekingerite, and the other minerals include smithsonite, pyrite, quartz, opal, fluorite, and calcite. The deposits are found in hydrothermally altered portions of a quartz monzonite stock. In some places the ore forms along well marked fracture systems, but elsewhere the alteration and fracturing is widespread with no distinct trend.

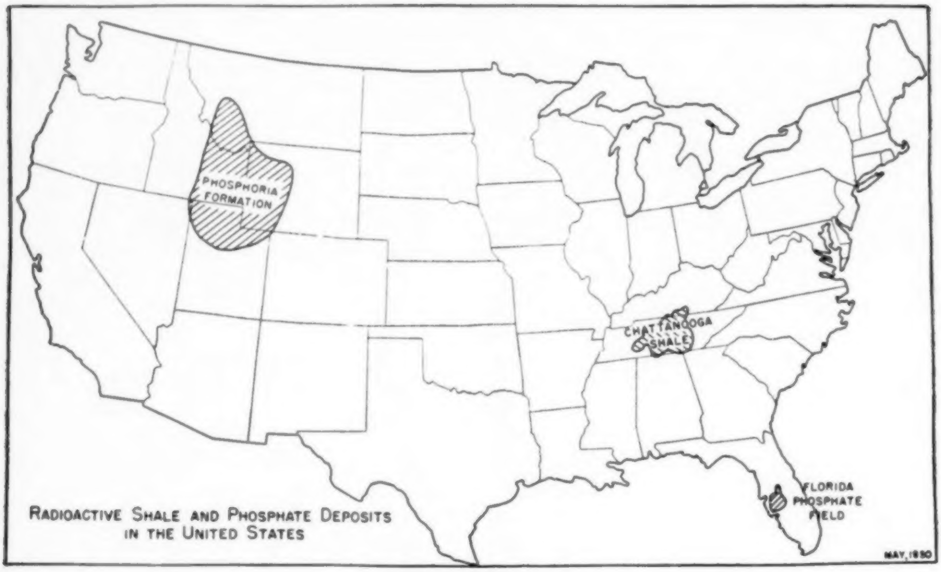
Most of the exploration to date has been done at the surface and the ore has been shipped from open pit operations. However, Vanadium Corporation of America has done a small amount of underground exploration and these workings have cut pitchblende-bearing veinlets at a depth of about seventy feet below the surface. This work has established that at least some of the secondary minerals mined at the surface are derived by the weathering of primary pitchblende. Thus there appears to be a good possibility that the secondary ores may give way in depth to primary uranium deposits.

A comparable relationship has been established in certain uranium deposits of Portugal. Here mineralization is controlled by northeast trending fissure zones in granite. At the surface the fissures carry autunite, metatorbernite, and uranophane, along with red jasper, quartz, and some relics of weathered pyrite. Weathering is intense in the arid climate of this part of Portugal, and the veins are leached and oxidized to a considerable depth. Exploration has shown that below fifty meters some of the veins carry pitchblende, and these primary deposits are now producing uranium ore.

At Marysvale and in Portugal underground exploration has demonstrated that the secondary uranium mineralization at the surface has primary roots in depth. There are similar-appearing deposits elsewhere in this country and abroad. Most, however, have not had the benefit of underground exploration, and the origin of these is still problematical.

Such an area is the White Signal district in New Mexico. The presence of secondary uranium minerals here has been known for many years, and several decades ago efforts were made to mine radium ore here but these proved commercially unsuccessful.

The country rock in the White Signal district is pre-Cambrian granite cut by a complex series of monzonite, diabase and felsite dikes, as well as steeply dipping faults. Nearly all the concentrations of uranium minerals — torbernite, metatorbernite, and autunite — are distributed along the margins of diabase dikes and along faults. Geologists who have studied the area have divided opinions about the deposits. On one hand, there are those who believe that the autunite and torbernite were formed by the reaction of uranium-bearing solutions derived from the granite with phosphatic solutions derived from the diabase. As such the uranium mineralization is solely a near-surface phenomenon. The alternative interpretation, held by other geologists, is that the secondary uranium phosphates are the sur-



The three major radioactive shale and phosphate deposits in the United States are the Phosphoria formation of the western states, the Chattanooga shale of the east-central states, and the Florida phosphate field. Courtesy of the U. S. Atomic Energy Commission.

face expression of weathered pitchblende-bearing veins. As such there may be primary ores in depth. There the question now lies. Its solution will await the exploration of the mineralized zones below the zone of oxidation by diamond drilling or underground exploration.

Uranium in Sedimentary Rocks

The third recent trend which I would like to mention is the attention being given to sedimentary rocks as possible uranium reserves.

The world's uranium supply now comes from high grade, comparatively small deposits, that is, from pitchblende veins and carnotite ores containing more than 0.2% uranium. These deposits all have finite lives. It is impossible to predict how long the high grade reserves of uranium will hold out, because the rate of exhaustion depends on varied factors, many of which are unpredictable. But judging from past experience with other metals we might expect that as rich deposits become depleted and the rate of new discovery declines, more and more attention will be devoted to low grade, large scale reserves.

It has been known for many years that some sedimentary rocks contain significant amounts of uranium. Portions of the alum shales of Sweden have been reported to carry as much as 0.5% uranium. Newspaper reports during the past few years indicate that Sweden and possibly Russia are recovering uranium from oil shales. What are we in the United States doing about these deposits?

For several years the U. S. Geological Survey, on behalf of the

URANIUM CONTENT OF ROCKS

Material	Uranium Content
Pitchblende — mineral	80% or more
Pitchblende — ore	variable
Carnotite ore	0.2%
Phosphorite	0.0x%
Black Shale	up to 0.0x%
Marine sandstone	0.0x% to 0.000x%
Limestone	0.000x%
Average of earth's crust	0.0005%
Sea Water	0.0000002%

Atomic Energy Commission, has been evaluating our sedimentary rocks as possible uranium resources. The work of the Survey indicates that two rock types, in particular, contain abnormally high concentrations of uranium. These are: first, marine black shales and, second, marine phosphates. The radioactive black shales are of the bituminous type, from which oil can be distilled, rather than the carbonaceous or coaly shales. The shales with high uranium values are also characterized by scattered pyrite and marcasite.

In passing we might note the inverse relation between the uranium content and the carbonate content of rocks. As indicated in that table most limestones are low in radioactivity. In the phosphorites and black shales, too, the limy beds contain less uranium. I mentioned earlier in noting the characteristics of uranium veins that limestones rarely provide favorable host rocks for these deposits. And in the ores of the Sunshine mine in Idaho siderite is the most abundant gangue mineral, yet the pitchblende forms almost exclusively in quartz and avoids the siderite. This association is particularly striking on a microscopic scale. This antipathy of uranium for carbonate rocks undoubtedly results from the fact that the uranyl ion has high solubility in solutions containing carbonate ions. Hence, precipitation of uranium from solutions does not take place readily in a chemical environment with a high concentration of carbonate.

Deposits of radioactive black shales and phosphates are fairly common in this country. Among the black shales, the Chattanooga shale of east-central United States, and its equivalents in the mid-continent area, has received most attention to date. Our uranium-bearing phosphates are in two widely separated areas: the land pebble field of Florida and the deposits in the Phosphoria formation of the western states. Both of these areas are now producing phosphate for fertilizer, and there is a possibility of obtaining uranium as a by-product.

The utilization of these reserves is perhaps more an engineering than a geological problem. The geologist can promise large reserves of these low grade uranium-bearing rocks; can the chemist develop methods of profitably extracting the marketable products? Given a radioactive phosphate rock: can mining, milling, and refining methods be devised so that the phosphate, the uranium, and other products can be extracted at a profit? Given a carbonaceous black shale: is it possible to extract the oil, the uranium, and other marketable products at a profit? This is indeed a challenging problem for industrial science. In processing these low grade resources we might well be guided by the meat processing industry which boasts that it processes — and sells — everything but the squeal.

Conclusions

To sum up briefly I have noted several recent developments which promise to improve our available resources of atomic raw materials:

First. Recent Canadian discoveries of primary uranium ores point to increasing production there.

Second. New discoveries of pitchblende in mines of this country suggest that uranium ores may be discovered in other untested mines.

Third. In two localities it has been demonstrated that secondary uranium minerals are the surface expression of primary uranium veins. Similar mineralization elsewhere may prove a lead to new ore bodies.

Fourth. Reserves of uranium-bearing sedimentary rocks in the United States are being appraised, and research of the utilization of these ores may prove a key to uranium production from these sources.

The results of our exploration work to date are encouraging but each new development raises its own peculiar problems. These problems fall not within a single field but touch upon the work of the geologist, the engineer, the chemist, the physicist, the industrial scientist. Here are problems that challenge all of us, and our own security and welfare may depend on how ably we meet the challenge.

[This article was presented before the Mining Branch of the Southern California Section of the American Institute of Mining & Metallurgical Engineers in Los Angeles, Calif., June 14, 1950.]

Mineral Resources of Colombia Appraised

WASHINGTON, July 19 — Data concerning 29 mineral commodities of the Republic of Colombia gathered by U. S. geologists and engineers have been published as U. S. Geological Survey Bulletin 964-B. Author of the "Mineral Resources of Colombia (other than Petroleum)" is Quentin D. Singewald, Survey geologist and director of the data-collecting project which began in Aug. 1942 under the Foreign Economic Administration. The mission was mainly interested in strategic minerals, necessary at that time to the war effort. Petroleum resources were not surveyed.

Colombia is dominantly an agricultural country, but precious metals, emeralds, and petroleum are important export commodities. An excellent start has been made, the report says, in producing minerals and manufactured goods for the domestic market.

Emeralds, gold, platinum and silver are among the leading minerals produced mainly for export, while barite, cement, clay, coal, gypsum, salt, sand and gravel, silica and stone are mainly for the domestic market. A large number of other mineral commodities are listed as "raw" prospects, some of which may eventually become productive. A few commodities such as antimony, abestos, iron ore, mercury and sulfur have been produced in insignificant to small quantities.

Gold and emeralds are perhaps the two exported commodities for which Colombia has been most famous since the days of early Spanish exploration. Since 1537 nearly a billion dollars worth of gold has been mined in Colombia and the report discusses individually, the leading mines in each area. More than 150 occurrences of emeralds have been reported, but apparently only three — Muzo, Cosquez and Chivor (Somondoco) — have attained importance. The Muza mines have been consistently outstanding; worked intermittently they have produced more than $1,000,000 worth of gem stones during some years.

Barite deposits have been exploited in Huila, Norte de Santander, Santander, and Tolima, and promising deposits have been discovered in Magdalena. The demand for barite, chiefly for oil-well drilling, is expected to increase.

Cement was produced in 1945 by six plants, owned by five companies. The daily output was worth approximately $66,000, American currency. More can be used, hence five plants intended to expand capacity and two new plants will be built.

The total output of coal for Colombia during 1944 amounted to some 595,000 metric tons, valued at about $2,700,000. The coal ranges from a sub-bituminous to bituminous and locally will yield a low-grade coke.

Copper deposits are widespread, but probably not a single outcrop offers reasonable hope, if explored, of leading into a large, commercially valuable body

Iron ore has not been discovered in sizable deposits of superior grade. The most promising are those of Paz del Rio, Boyaca.

Lead prospects have been reported in six areas but only two in Santander and one in Caldas merit consideration as possible sources of ore for the domestic market. None seems promising as a source of ore for export.

Mica of excellent quality, both muscovite and phlogopite, may be procured in many places.

Molybdenum prospects are scattered through six areas notably in Tolima.

Platinum is mined from placer deposits in the Choco where it is associated with gold.

Salt is derived in Colombia from rock salt mines, saline springs, and marine salinas.

Silica for the manufacture of glass at factories in Antioquia, Caldas, and Cundinamarca is procured mainly from sandstones of Upper Cretaceous and Eocene age.

Silver is mined only as a byproduct of gold.

Sulfur occurs in very small deposits, formed by fumaroles and springs in proximity to volcanoes of recent age. The deposits have been exploited only to a very small degree; apparently they contain no substantial reserves.

Zinc prospects are scattered mainly in Caldas, Cundinamarca and Tolima.

During World War II, quartz crystals were procured from Boyaca, Antioquia, and several other departmentos. Some 2,430 pounds were shipped, of which 1,503 pounds, valued at $7,870, was accepted. The crystals were generally derived from small lodes by underground mining and the cost of production greatly exceeded the value of the crystals.

The locations of the various mineral deposits reported on by Mr. Singewald have been plotted on 9 plates using a base generalized from an American Geographical Society map. These are contained in a pocket attached to the back cover.

The report states that transportation costs are excessively high in Colombia which retards mining and manufacturing for export but automatically protects mines and factories that produce for local markets.

"Although airplane service is available between a number of points including several of the mines," according to the report, "the main arteries of travel are the railroads, the highways, and the lower courses of several large rivers. Railroads and highways are costly to build and, during the rainy season, difficult to maintain."

The author explains that neither a satisfactory account of the general geology of Colombia nor an adequate setting for local geologic details at specific prospects could be given, because many of even the salient features remain undeciphered. Nevertheless, the present work does provide a synthesis of published information particularly valuable as a background for mining men interested in the geologic features.

Earth Science Abstracts

[Selected articles on the earth sciences, appearing in current scientific publications, are abstracted here for the convenience of our readers.]

ASTROCHEMICAL PROBLEMS IN THE FORMATION OF THE EARTH. Wendell M. Latimer. **Science**, Vol. 112, No. 2900 (July 28, 1950), pp. 101-104. It is assumed that the earth was formed by the condensation of a cold cosmic cloud, separating the solid particles present from the gaseous excess and bringing them together to form the earth in its initial state: a central core of iron (with about 8% nickel), surrounded by a mantle of magnesium and iron meta- and orthosilicates, and an outer layer of basalt. No surface water, atmosphere, or granite masses (continents) were present in the initial stages.

GLACIATIONS IN LITTLE COTTONWOOD CANYON, UTAH. Ronald L. Ives. **Sci. Monthly**, Vol. 71, No. 2 (Aug. 1950), pp. 105-117. A discussion of the early Cambrian (?) glaciation, Pleistocene glaciation, postglacial features, and datings and correlations with the glacial stages in the Monarch Valley, Colo., and adjacent areas.

FLOW OF HEAT IN THE FRONT RANGE, COLORADO. Francis Birch. **Bull. Geol. Soc. Am.**, Vol. 61, No. 6 (June 1950), pp. 567-630. The flow of heat at the Alva B. Adams Tunnel under Rocky Mountain National Park, Colo., is computed as between 1.6 and 1.9 microcal/cm^2-sec, with a "best value" of 1.7 microcal/cm^2-sec, differing significantly from the best values for a "normal" sea-level crust, which fall close to 1.1 microcal/cm^2-sec. This difference of heat flow may be accounted for in terms of mountain roots having a mean radioactivity of the same order as that of granites or intermediate rocks. It is consistent with Airy's conception of mountain roots and with an approximately uniform distribution of radioactivity throughout the "granitic" layer. Other possible explanations for this high flow of heat are: (1) mechanical compression; (2) initial heat of a non-radioactive root; (3) subcrustal currents; (4) intrusion of magma. Corrections have been applied for the topography on several different hypotheses regarding the physiographic history.

Water Resources

JUNE 1950

Stream flow in the Pacific Northwest was sustained at high levels during June, but extraordinary floods did not occur. Apparently most streams have passed their seasonal peaks and insufficient snow remains to cause concern for large floods from the source.

Winnipeg River reached a record-high stage and runoff continues high in the Minnesota region as most streams receded slowly from the record floods of April and May.

Local floods of record-breaking size occurred in small drainage basins from Pennsylvania to Nebraska. The flood on West Fork River in West Virginia exceeded the 1888 maximum.

Although runoff for June was well above normal along much of the Atlantic slope, end-of-month flows were generally below normal. Deficient runoff continued in Nova Scotia with a new low record for June in St. Mary River.

Drought conditions continue in the Southwest.

Ground-water levels declined seasonally where there was heavy pumping for air conditioning.

— WATER RESOURCES REVIEW

SEDIMENTATION STUDIES AT LAKE MEAD

HERBERT B. NICHOLS

U. S. Geological Survey

Determination of the useful life of Lake Mead, the large artificial lake behind Hoover Dam, on the Colorado River, under circumstances now prevailing, involved many avenues of scientific investigation and engineering skills to arrive at a realistic conclusion. The result has been the completion of one of the most carefully planned scientific studies of an area with the physical and chemical forces at work, that has ever been accomplished.

The work was done at the request of the U. S. Bureau of Reclamation by scientists of the U. S. Geological Survey, aided materially with equipment, personnel, and special techniques of the Navy Department. In addition, valuable assistance was generously given by scientists of other government bureaus together with experts from several universities and institutions of higher learning. Two years were required to plan the operations, assemble equipment, gather comprehensive data, and accomplish the required interpretations. The results have been most heartening, for it is now known that, whenever effort is expended to take the salt and silt-laden pulse of any stream, knowledge can supplant "guesstimation." The data gathered will doubtless influence engineering and construction practices for generations to come.

Such a combination of skills in many branches of science has seldom before been combined for the solution of such a problem. Facts were needed, not only to determine how fast Lake Mead will accumulate sediment dropped by a river whose swiftly moving water loses most of its silt load when slowed down to lake speed, but to find out whether new areas of salt-laden rocks now open to the chemical action of groundwater might spell ruin for lands downstream.

At stake was the government's whole regional administrative program of areal improvements whereby water storage, irrigation projects, power production, and erosion control efforts are today combined to open undeveloped lands and natural resources to pioneers. Can the United States, through engineering skill, still keep such areas as the Colorado, Missouri, and Columbia River Basins on the asset side of the ledger so far as considering them potential "new frontiers"? We now know the answer is "yes". The principal elements influencing the life of at least one great dam, and the artificial lake it produced, have been carefully examined.

What were the essential questions asked? Primarily, it was necessary to find out how much mud, silt, and sand had been dumped into the Lake since the water backed up to spillway level; also, how much and what kind of salts are now being drawn out of the surrounding rocks through

LAKE MEAD AND HOOVER DAM. [Bureau of Reclamation photo.]

chemical action at new ground water levels.

Limnologists of the Survey's Quality of Water Branch at Albuquerque, New Mexico, experts in the physical and chemical content of fresh-water lakes and ponds, analyzed hundreds of water samples to determine that the amount of salts or solids found in Lake Mead varied with the location and depth of the collecting point as well as with the season.

They found that the principal dissolved solids are silica, and salts of calcium, magnesium, sodium, potassium. The decrease noticed for this body of water near the surface of the lake was chiefly in calcium and bicarbonate, a fact that gives further support to the theory that calcium carbonate is being precipitated during storage.

In order to give utmost meaning to such studies as these, it became quite obvious that the quality-of-water studies should be continued so as to include not only the lake but the feeder streams and springs, keeping careful records of where and when each sample is collected. Obviously, more salts will dissolve out of the ground and be dumped into the lake at some seasons of the year and in some localities than in others.

However, the staff available and the water samples analyzed were not sufficient to determine where the heaviest waters come from, or what happens to water of varying density added to the lake by the Colorado. It is certain, however, that at some periods water with a high concentration in dissolved solids or high in fine sediment content flows into the reservoir for considerable distances without appreciable mixing.

The limnological studies undertaken exposed as groundless, fears expressed during the planning stages of Hoover Dam that a salt lake might be created because of the presence of large beds of soluble salts in parts of the reservoir site. Some objections were based on the alleged high boron content which would be detrimental to irrigated areas; others on the high fluoride content which it was thought might be harmful to children using the water for drinking purposes. Chemical analyses show such concentrations to be way below the danger level.

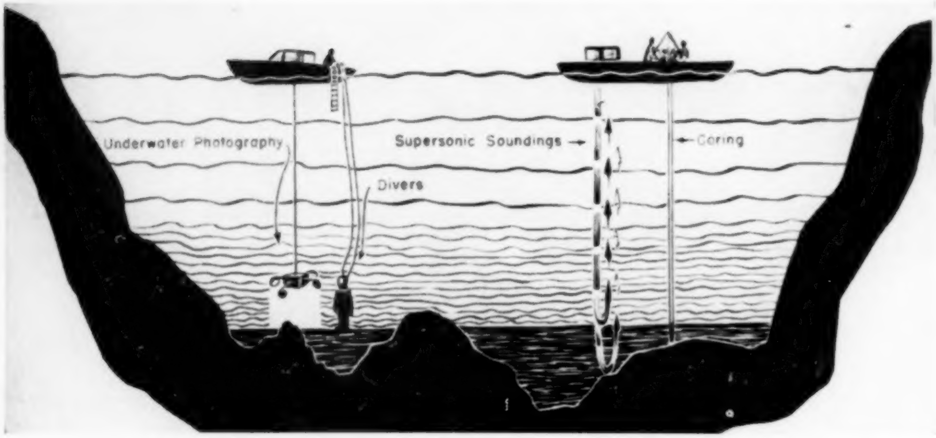
As a vital part of the work, the U. S. Navy Electronics Laboratory (NEL) was asked to assist in planning the study, to furnish special oceanographic and other equipment, and to conduct a study of the water circulation in the lake. This latter phase was undertaken by the Physical Oceanography Group of NEL, whose personnel worked each month an average of 65 stations distributed all over Lake Mead. For more than a year they gathered data from a small boat in all sorts of weather. These were the men who collected the water samples analyzed by Dr. C. S. Howard's laboratory in Albuquerque. They also took vertical profiles of the temperature distribution at each station with the bathythermograph, an instrument that makes a continuous record of the change in temperature with depth. The temperature data, with the salinity analyses made by Dr. Howard's laboratory, were then analyzed by the NEL group to determine water movement.

A "water mass", like the air masses whose movements are responsible for changing weather conditions and storms, has individual characteristics that can be measured and identified. Most useful is the "T-S relation," the relative temperature and salinity of the water mass. By plotting the "T-S relation" at various depths at each station in Lake Mead, the circulation was determined, showing that the water in the Lake moves in different ways at different seasons.

In the winter, the cold, relatively more saline water of the Colorado River is heavier than Lake Mead water, and "dives" below the surface at the head of the lake. It flows along the bottom all the way down to the lower Basin. Meanwhile, surface water moves up the lake to replace lake water dragged down by the plunging river water, so that near the head of the lake, water near the surface actually flows upstream! The upstream-flowing water of the lake meets the downstream rushing waters of the Colorado River at a definite line, marked by driftwood forming great "boils" of turbulent water.

Contrasting conditions prevail during the late spring. The lower salinity of the Colorado River water makes it lighter than the lake water, so that now the river water flows downstream on the surface, with a return flow upstream along the bottom.

In addition to studying the circulation of Lake Mead, the NEL group showed that the temperature and salinity data could be used to advance our knowledge of the relationships between the atmosphere and water bodies, and of the energy exchange that takes place between the air and water.



UNDERWATER METHODS OF INVESTIGATION AT LAKE MEAD
[Courtesy of the Bureau of Reclamation]

Another fascinating side of the investigations (but a muddy side, say those who conducted them) were the core studies. Some 1600 cross-sections of sedimentary (mud) layers were obtained, using core techniques developed by oceanographers. In this work a long hollow tube about two inches in diameter, lined with plastic to permit easy handling of the contents, is plunged into the mud. When it is pulled up, it contains a complete record of each layer from top to bottom. Some cores as long as 90 feet were obtained.

The 1600 cores, collected at the rate of about 4 or 5 a day, were then split down the middle and studied microscopically to determine where and what kind of sediments are being deposited, how fast sediments are collecting at various points, and how much they weigh. Then combining chemical and microscopic techniques, it was determined about how long it would be before such layers will compact or lithify (change to rock). As consolidated sediments take up less room than unconsolidated, when solidification takes place the sediments will occupy less space, adding more decades to reservoir life.

Dr. M. G. Leifson of the Navy Hydrographic Office explained that in order to determine the amount of bulk sediment being dropped, fathometers were used. Such instruments project sound waves downward from a ship's bottom and automatically translate into fathoms the length of time it takes such waves to hit bottom and be reflected back to the instrument. With sea-bottoms well charted in the vicinity of shipping lanes, a navigator can almost feel his way along by comparing fathometer readings with his chart.

Carl G. Paulsen, Chief Hydraulic Engineer of the Geological Survey, explains that in building a hydrographic survey of Lake Mead, the objective was not navigational information but a determination of the volume of sediment and the total capacity of the reservoir. Hence this survey was reduced to its most elementary form: measuring true depths below a known datum plane and fixing the position of such measured depths in true relation to a geodetic control net on shore.

This triangulation net was established by geodetic engineers of the Geological Survey, and consists of a series of accurately located reference marks around the shores of the Lake. These are permanent marks, and can be used again and again by future surveys and investigations. There are 307 of the shoreline marks, and 26 additional triangulation stations were used in the surveys needed to tie them to each other and to the basic points of the Coast and Geodetic Survey in a rigidly surveyed network.

Lt. Carr McCall of the Navy Bureau of Ordnance, whose duties included care and operation of the fathometer, explained that this instrument not only tells a navigator where the bottom lies but distinguishes between echoes that come back from mud surfaces and echoes that have penetrated the mud to be reflected by rockbottom. Subtracting one from the other gives the depth of the mud. As it is obviously impractical to measure the depth at every point, the submarine relief had to be deduced from a systematic series of depth measurements spaced at proper intervals to determine slope.

Before the physical conformation of the reservoir could be determined, Navy hydrographic methods had to be combined with topographic mapping methods used by survey engineers in making the original land maps of the area. This meant cross-indoctrination in several methods of gaining data. Seagoing chart-makers use somewhat different techniques than did the men who worked on land with engineer's transits, and in the air surveying cameras, to produce the original land maps of the reservoir site just before it was submerged beneath Lake Mead.

Yet both were needed here. On the whole, shore and shipborne survey crews worked perfectly together. They experienced no more than the usual difficulties one might expect during hours when weather is excessively hot and humid, or on windy days when choppy waves made accurate surveying impossible. The problem of signal visibility was more dfficult too at Lake Mead than would be commonly true elsewhere. Objects and men viewed from a distance tended to blend with the mottled gray and light-brown rock, sand, and brush comprising most of the lake's shore; and during the summer, the shimmering desert heat with consequent optical distortion further limited clear vision.

For the most part, shore signals erected on the geodetic reference marks on which the hydrographic survey instruments were focussed, consisted of 16-foot masts of 2-inch, light iron pipe pointed in the middle and guyed with 7 cables. Each mast supported a "skirt" made of 3 triangular sections of fabric. White Indian-head cloth proved best for visibility and also withstood buffeting by heavy winds.

By taking sights to these shore signals, the hydrographers out on the Lake could locate themselves accurately at any time, when making soundings, taking samples of silt, or making other desired observations. However, errors were all relatively small and tended to be compensating.

R. W. Davenport, Chief of the Survey's Technical Coordination Branch, said that the hydrographic survey showed that Lake Mead contains 1,423,000 acre-feet of sediment, of which 600,000 acre-feet is below the dead storage level. Silt has been deposited in the reservoir at an annual rate of 105,500 acre-feet since water storage was started in 1935. This is extraordinarily close to the figure of 105,000 acre-feet in the Weymouth report, issued in 1924.

The total capacity at spillway level (gates raised) is now 29,827,-000 acre-feet compared with an original capacity of 31,250,000 acre-feet. New area-capacity tables have been prepared from the hydrographic survey for use in future calculations of the water budget and operations of Lake Mead, and may be examined in offices of the Geological Survey at Washington, D. C., and at Tucson, Arizona.

Lake Mead is roughly a large "Y" in shape with its base at Hoover Dam in Black Canyon. The north fork is the submerged channel of the Virgin River, the south fork is the submerged Colorado.

In his outline of the geographic and geologic setting of the Lake Mead Reservoir, Professor Chester R. Longwell of Yale University notes that bedrock in the area near the lake is highly varied in both kind and mode of origin. Rock materials of the highlands, he says, are generally older and more resistant then those flooring the basins. In fact a considerable part of the material exposed in the basins consists of detritus that was eroded from the highlands, and is still either unconsolidated or only moderately turned to rock. The oldest bedrock consists of banded and micaceous metamorphic rocks (gneisses and schists).

In considering the tributary drainage basin that feeds Lake Mead, H. E. Thomas of Salt Lake City notes that the water and sediment accumulating in the lake come from a region that extends far beyond the limits of the area encompassed by the reservoir survey — that it includes some 168,000 square miles or roughly fiive percent of the continental area of the United States — very little of which is adapted to gracious living in the American style because it is so mountainous and lacking in moisture.

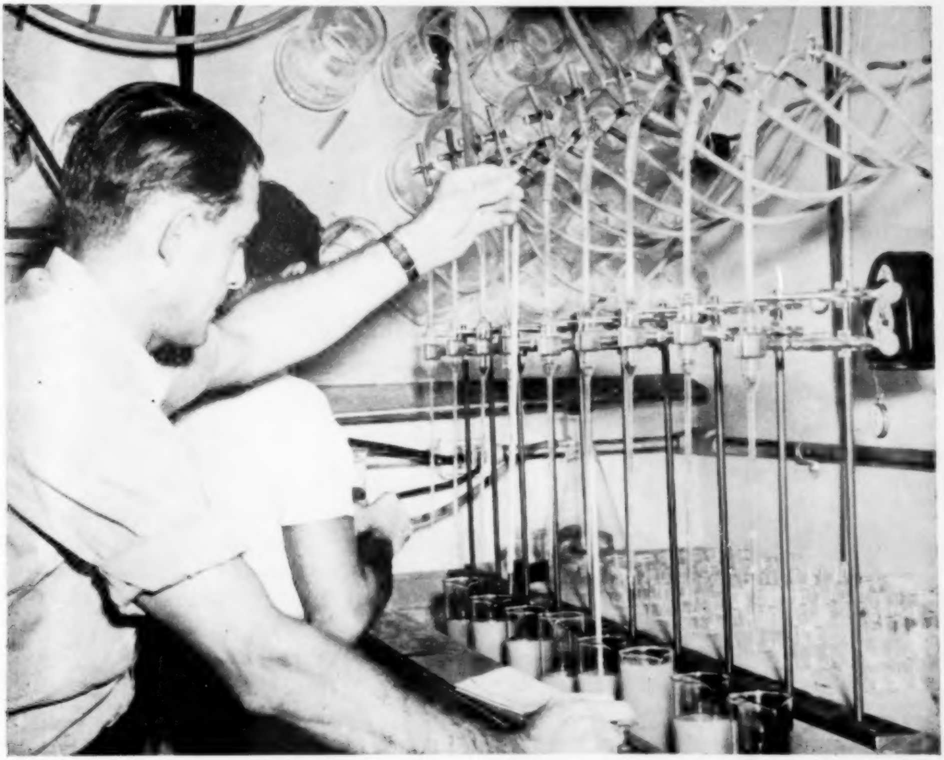
Survey geologist Howard R. Gould, now at the University of Southern California, reports the sediment accumulated in the Lake from February 1935 to January 1949 has formed two long deltas. One extends from the original head of the reservoir to Hoover Dam along the former channel of the Colorado and the other, much smaller, extends south from the mouth of the Virgin River.

With the exception of a small amount of sediment contributed at four places by slumping of the reservoir walls and by the precipitation of silica and calcium carbonate (rock-forming materials carried in solution in the lake water), all the sediment of these deltas has been supplied by the two rivers.

No important alteration of the shore line attributable to wave action was observed, according to Mr. Gould. He noted a few steep-sided headlands of rather loosely cemented sand and gravel, subject to undercutting and caving along the north shore of Boulder Basin and on the east shore of Overton Arm. Blocks of material have sheared away and lie at the base of such headlands, but it is not known just what part of this disintegration occurred as a result of normal weathering long before Lake Mead was formed, and what part has occurred since as a result of wave cutting.

At any rate, such areas are small. Except for the few gravel headlands and the durable rock-walled canyons, most of the Lake shore is moderately sloped and is not subject to serious undercutting and caving.

In addition to the shore proper,



The pipette method of mechanical analysis for determining the sizes of the particles in a sample of sediment. The larger particles settle out faster, according to a known relationship. Aliquots are taken with the pipette at certain fixed times and depths, which establish the speed of settling and also show the size. The pipette aliquots are then dried and weighed. The weight of each sample is proportional to the percentage of material of the particular size. This photo shows a battery of 10 settling cylinders and pipettes, for turning out analyses in volume. The temperature is measured periodically during the run because the speed of settling depends partly on the temperature of the suspension. Photo by Wm. S. Russell.

islands and some submerged peaks undergo wave erosion. This is quite evident in places, with ten to fifty feet of material gone from the tops of some prominences. Erosion of this nature is most marked in Las Vegas Bay, where islands and offshore shoal areas are encountered with a frequency much greater than that common to the rest of the lake. Hence the conclusion that any estimate of island and shoal erosion made for Las Vegas Bay must be materially reduced if it is to serve as an index of such changes over the entire lake.

Mr. Gould says further that the studies of approximately 1600 samples collected from the sediment deposit provide abundant quantitative information on some of the fundamental problems of sedimentation. For example, slightly more than two billion tons of sediment have accumulated in Lake Mead, and this material now occupies about 5 percent of the reservoir storage below the spillway level (1205.4 feet).

"Perhaps the most striking feature of the deposit," he says, "is the extreme fineness of its particles (largely silt and clay) and the virtual absence of coarse stream gravel, even in the upstream portions of the deltas exposed above the mean operating level of the lake. The fine texture of the material, together with the rapid rate of sedimentation, accounts for the lack of compaction of most of the deposit."

From figures on the rate of sedimentation, the rate of sediment compaction, and the capacity of the reservoir for storing sediment above the lake level, Geological Survey hydrologists computed the now generally accepted estimate of the time required for the reservoir to become filled with sediment, assuming that the rate of incoming sediment continues the same as at present.

Plotting the mean elevation of the deposits of sand and the finer silts and clay as two separate curves projected against a background of time, it is found that they intersect at a point 445 years from the date Hoover Dam was completed, or at about 2380 A. D. That is the approximate year, they agree, when silt will have completely filled the reservoir, if the present rate of sedimentation continues.

Yet this does not mean that it will lost its usefulness then, for water in motion will always dig a channel sufficient to take care of its immediate needs. This means there will always be "run of the river" water available; than even 445 years from now the giant waterwheel generators will be able to run at about 75 percent of present capacity, and that some water will be available throughout most of the year for irrigation. But because by 2380 there may be no reservoir of water to draw on in February, there can be little water at that time to take care of the "extra" demand early-crop farmers have learned to expect. At other seasons of the year they will have nearly as much water as ever.

It is, however, desirable to postpone the filling of Lake Mead as far into the future as possible. Hence, engineering plans have been proposed whereby distant upstream erosion dams will arrest soil movement. Others located near the head of the lake might provide gates, which in connection with tunnels acting as siphons, would enable the heaviest silt-laden waters to be shunted around the lake and directly through the power-house sluiceways.

Such control dams and siphon-tunnels could extend any reservoir's usefulness indefinitely. In fact, some engineers feel that to build only half of such a system (as has been the rule thus far) is to encroach upon the heritage of generations to come to save a few dollars now. There is no excuse for turning over silt-laden reservoirs to our children's children.

Reclamation's hydraulic engineer Leslie C. Pampel, reporting work accomplished in the so-called "Lower Granite Gorge" portion of upper Lake Mead (between Bridge Canyon and Pierce Ferry) says this section is almost completely filled with sediment. Comprising about 3 percent of the total water surface of the lake, it now contains about one-third of all the sediment deposited.

Because of extreme silting here, coupled with biological changes in the sediment due to the activity of low forms of living matters, unusual problems arose. For example, great sunken areas caused by gas pockets were found in the mud and an attempt was made to determine the interrelationships between changing temperature, decomposing organic matter, and gas volume.

However, according to Carl H. Oppenheimer and Frederick D. Sisler of the Scripps Institution of Oceanography at La Jolla, California, who prepared the report on "Bacteriology and Biochemistry of the Lake Mead Sediments": — "Although it appears quite evident that micro-organisms are abundant and active in the Lake Mead sediments, much of the biochemical change taking place can only be determined by observations of the sediments over a period of time. In this manner, the direction of the natural changes taking place may be determined."

Most of the work accomplished by the Scripps representatives was done near Hoover Dam itself where the high temperature of recently precipitated sediments was a principal point of interest. Their report leaves little doubt that biochemical activity catalyzed by micro-biological agents inhabiting the thick layer of soft sedimentary material have contributed substantially to the heating of the mud.

Yet the extent to which this affects lake water temperature and hence evaporation "cannot be estimated," they conclude, "unless all the factors which influence the heat budget are evaluated. Continued observations over a period of time should be made if one wishes to predict with any measure of success the direction and ultimate equilibria of the diversified biochemical reactions now taking place."

Dr. Charles B. Hunt, Chief of the Survey's General Geology Branch, points out in summarising Lake Mead erosion and sedimentation problems, that much more study is needed, if we are to avoid the waste inherent in visionary engineering and reclamation programs founded on inadequate knowledge.

"We have become quite familiar with the sickening sight of fertile hillsides being gutted by gullies, or of lush floodplains made desolate by arroyo cutting. The fact of erosion is accepted and there is general agreement too that something should be done about it. There, however, agreement ends, even among the experts.

"One school blames man for erosion. Overgrazing and poor farming practices are cited as the cause of much if not all of the erosion we are witnessing. In support of this is the fact that erosion in much of the West did not start until after the land became used for livestock or agriculture.

"Another school, however, believes that man did no more than hasten the beginning of a cycle that would have started very soon even if the land had not been used for agriculture or grazing. In support of this is the fact that identical arroyo cutting and gullying has occurred repeatedly during prehistoric times when man was not here to upset the balance.

"An intensive research by a considerable variety of specialists is needed," he concludes, "reviewing the three principal disciplines utilized for approaching such problems: (1) historical or stratigraphic method, (2) statistical or geographic method, and (3) experimental method.

"The historical or stratigraphic method", he explains, "seeks to solve problems by developing a chronology of past events which may disclose relationships between causes and effects and further uncover natural laws that have controlled the processes in the past. The statistical or geographic method seeks to solve problems by classifying, mapping and plotting the effects of present-day erosion, and the distribution of deposits now being formed. The experimental method seeks to learn the relationship between causes and effects by reproducing the processes under controlled conditions and observing the effects of variations in the conditions.

"In erosion and sedimentation work, all three methods are needed."

Opportunities For Lecturing and Research Abroad Under the Fulbright Program

WASHINGTON, July 24 — Approximately 300 awards for United States citizens to serve as visiting lecturers or to engage in research in institutions of higher learning abroad during the academic year 1951-52 have been announced by the Department of State under the provisions of Public Law 584 (79th Congress), the Fulbright Act.

Many of the awards are open to applicants in the fields of geography and geology. Countries now participating in the program are Australia, Belgium - Luxembourg (including the Belgian Congo), Burma, Egypt, France, Greece, India, Iran, Italy, Netherlands, New Zealand, Norway, the Philippines, Turkey, and the United Kingdom, including the British Colonial Dependencies.

In addition to the large number of awards offered without specification of subject or sponsoring institution, attention is called to the following specific opportunities in geography and geology and related fields at certain designated institutions abroad.

Burma

Geology: Burma offers unusual opportunities for research in geology because of its wealth of mineral resources and its interesting structural features. The visiting scholar in geology would be attached to the University of Rangoon, which is especially interested in sponsoring a specialist in stratigraphy, paleontology, or economic geology. Applicants should note that the academic year begins in Burma in late June and ends in March. The successful candidate should also be prepared to give invitational lectures in his field of specialization.

Egypt

Paleontology: Farouk I University in Alexandria has expressed an interest in receiving a visiting lecturer in this subject. Additional details regarding this opportunity are expected in the near future.

Netherlands

Geology: Although no particular aspect of the subject is given preference, geology is among the subjects in which a visiting lecturer would be welcomed at the University of Utrecht.

Norway

Geography, Geology, Mineralogy: The University of Oslo has included these subjects among those in which it offers the greatest opportunities to American research scholars.

New Zealand

Offshore Sedimentation: The Museum Association of New Zealand has proposed that an American scholar participate in an investigation into the origin and distribution of the sediments at present forming on the continental shelf around New Zealand. In addition to its general geologic importance, this project has significance for determination of the horizons and extent of coal and limestone deposits.

Oceanography: The Museum Association of New Zealand is also interested in sponsoring research in oceanography as a part of the Pacific-wide program of oceanographic research recommended by the seventh Pacific Science Congress. Although a specialist in marine biology or an experienced director of oceanographic research would find more of interest in the way of current research in New Zealand, the opportunity is also open to a specialist in the physiochemical, meteorological or physiographic aspects of oceanography.

Geophysics: The Department of Scientific and Industrial Research offers an opportunity to an American geophysicist with a background in engineering to collaborate with a team of New Zealand scientists on investigations of the Rotorua Thermal Area. The geophysical section will carry out gravimetric, electrical, airborne magnetometer and seismic surveys, and investigations into drilling and thermal conductivity and specific heat of rocks.

[NOTE: As the number of awards available for research in New Zealand is limited to three and as these are open to applicants in other fields as well as to applicants in geology, it should be kept in mind that an award may not be made in connection with each of the projects listed above, although all applications will be carefully considered. It should also be noted that the academic year in New Zealand begins in March and ends in December.]

Philippines

Economic Geography: Although not on its priority list, economic geography has been included by the University of Philippines in the list of alternative subjects in which a visiting lecturer from the United States is desired. The academic year in the Philippines begins in late June and ends in March.

United Kingdom

Most of the awards available for lecturing and research in the United Kingdom are offered without specification of subject or receiving institution. The following universities or university colleges, however, have indicated an interest in receiving American lecturers or research scholars in geography: Aberdeen, Bristol, Cambridge, Edinburg, Liverpool, London, Nottingham, St. Andrew, Sheffield, Hull, Leicester, Southampton, the University College of Ibadan in Nigeria, Raffles College in Singapore and Makarere College, Uganda, East Africa. An interest in specialists in geology has been expressed by the Universities or University Colleges of Aberdeen, Birmingham, Bristol, Cambridge, Edinburgh, Liverpool, Manchester, Southampton and Nottingham. Since it is desirable that American grantees be distributed widely throughout the British university system, applications made with a view of attachment at universities other than Cambridge, London and Oxford are especially encouraged.

Other Countries

Programs for Australia and Turkey will be announced by the Department of State in the near future. It is anticipated that opportunities will be provided for research in Australia in economic geography (human settlement types) and in geology (invertebrate paleontology). Opportunities for lecturing in physical or human geography are anticipated in Turkey.

The closing date for filing applications for awards for lecturing and research for the academic year 1951-52 is October 15, 1950. Requests for application forms and for further information concerning opportunities for visiting lecturers, research scholars and specialists should be addressed to the Committee on International Exchange of Persons, Conference Board of Associated Research Councils, 2101 Constitution Ave., Washington 25, D. C.

New Books

All books listed here are deposited in the Library of The Earth Science Institute and may be borrowed by the members. Books marked with an asterisk may be purchased through The Earth Science Publishing Co., Revere, Mass.

*PRINCIPLES OF SEDIMENTATION. W. H. Twenhofel. 2nd Edition, 1950. xii, 674 pp., 81 figs.; $6.50. (McGraw-Hill Book Co., New York.)

In this revision the same approach and organization has been kept, but it has been brought up to date in presenting the progress made in the study of marine sediments and sedimentary processes in the sea. The concept that sediments are the products of heritage and environments is emphasized. The environmental factors, origins, transportation, deposition, formation, classification, textures and colors of sediments are considered. A highly recommended college text for an introductory course in sedimentation.

*ECONOMIC MINERAL DEPOSITS. Alan M. Bateman. 2nd Edition, 1950. xii, 916 pp., 303 figs.; $7.50. (John Wiley & Sons, New York.)

The author has consolidated his treatment of processes by regrouping them and preceding them by general principles. The sections on hydrothermal processes of mineral formation, cavity filling, replacement, sedimentation, and weathering processes have been reorganized and consolidated. Mineral deposits are treated according to the processes of formation instead of by a classification of mineral deposits. Detailed treatment is given to magmatic deposits, oxidation, and supergene enrichment. In order to prevent the book from becoming outdated statistics in general are eliminated. The selected references have been brought up to the end of 1949, a total of 41 pages. A comprehensive treatise on both ore deposits and non-metallics, it is designed for use in either one- or two-term courses in economic geology.

*THE ADVANCED ATLAS OF MODERN GEOGRAPHY. John Bartolomew. 1950. iv, 155 pp.; illus.; $6.00. (Meiklejohn & Son, London; McGraw-Hill Book Co., N. Y.)

This new atlas introduces Bartholomew's Hour System of Geographical Co-ordinates, in which the world is divided into 24 **hour** zones of 15° longitude, each being sub-divided into 90 **Westings.** The quadrant from Equator to Pole is divided into 90 parts, each being sub-divided in 10 **Northings.** It is related to the World Grid, based on Greenwich, and avoids the confusion of reading east and west of a prime meridian. The atlas includes excellent full-color maps on the surface geology, structural geology, physiography, earthquake regions, oceanography, and soils of the world, as well as regional geological maps of the geomorphology and geology of Europe and the geology of the British Isles. An excellent treatment of 19 different types of map projections, climatic tables, and a list of geographical terms are included in this outstanding work.

GEOLOGIC DESCRIPTION OF THE MANGANESE DEPOSITS OF CALIFORNIA. Parker D. Trask et al. 1950. 378 pp., 20 pls., 12 figs.; $2.75. (Bull. 152, Calif. Division of Mines, San Francisco.)

A supplement to Bulletin 125, this volume contains a series of detailed descriptions and maps of several hundred manganese deposits arranged by counties. Bulletin 125, Manganese in California, by Olaf P. Jenkins, summarized the data procured by the U.S.G.S. in World War II, and included an outline geologic map of California showing the locations of manganese deposits. The present report describes in detail the individual deposits.

CAMBRIAN SYSTEM OF WEST VIRGINA. Herbert P. Woodward, 1949. xii, 318 pp., 52 pls., 10 figs.. $2.00. (Vol. XX, West Virginia Geologic Survey, Morgantown.)

This volume deals with the Cambrian rocks of West Virginia, together with certain older rocks whose precise age is uncertain, and a few small igneous dikes of probable Triassic age. This is the third volume by the author in a series on the systematic stratigraphy of the State (Silurian System of West Virginia, Vol. XIV, 1941, and Devonian System of West Virginia, Vol. XV, 1943).

*LET'S HUNT FOR HERKIMER DIAMONDS. Claude H. Smith, 1950. 48 pp., 15 figs.; $1.00. (Claude H. Smith, Geneva, N. Y.)

An interesting little (4¼"x6") booklet on these beautiful quartz crystals, which occur in the Little Falls dolomite of the Mohawk Valley in east-central New York. It includes discussions on the geology of the region, the best places to search, developing finds, and the varieties of crystals found.

OTHER PUBLICATIONS RECEIVED

GEOLOGY OF THE QUIEN SABE QUADRANGLE, CALIF. Carlton J. Leith. 1949. 60 pp., 11 pls., 6 figs.; $1.75. (Bull. 147, Calif. Division of Mines, San Francisco.) Includes **Quicksilver and Antimony Deposits of the Stayton District, Calif.,** by Edgar H. Bailey and W. Bradley Myers.

GEOLOGY AND MINERAL DEPOSITS OF AN AREA NORTH OF SAN FRANCISCO BAY, CALIF. Charles E. Weaver. 1949. 136 pp., 24 pls., 4 figs.; $4. (Bull. 149, Calif. Division of Mines, San Francisco.) Vacaville, Antioch, Mount Vaca, Carquinez, Mare Island, Sonoma, Santa Rosa, Petaluma, and Point Reyes Quadrangles.

GEOLOGY OF THE MACDOEL QUADRANGLE, CALIF. Howel Williams. 1949. 78 pp., 4 pls., 13 figs.; $1.75. (Bull. 151, Calif. Division of Mines, San Francisco.) Includes **Circular Soil Structures in Northeastern Calif.,** by Peter H. Masson.

SPECTROGRAPHIC ANALYSIS FOR VANADIUM IN KANSAS CLAYS. Albert C. Reed. 1950. 20 pp., 2 fig.; $0.10. (Bull. 86, Part 2, Kansas State Geological Survey, Lawrence.)

NATURAL GAS IN 1948; PETROLEUM in 1948. R. B. Harkness. 1950. iv, 102 pp., 7 figs.; free. (58th Annual Rept., Part 3, 1949, Ontario Dept. of Mines, Toronto.)

ASBESTOS IN ONTARIO. D. F. Hewitt. 1950. 7 pp., free. (Industrial Mineral Circular No. 1, Ontario Dept. of Mines, Toronto.)

TAIBI LAKE AREA, ABITIBI-EAST COUNTY. Rene Beland. 1950. iv. 20 pp., 9 pls. free. (Geological Rept. 40, Quebec Dept. of Mines, Quebec.)

A CHEMICAL STUDY OF THE PEATS OF QUEBEC. J. Risi, C. E. Brunette, D. Spence, and H. Girard. 1950. 36 pp., 6 pls., 7 figs.; free. (P.R. No. 234, Quebec Dept. of Mines, Quebec.) 1. — The "Clair" Peat Bog, Bellechasse County